Towards farming-systems change from value-chain optimisation in the Australian sugar industry

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Abstract. The supply chain of the conventional Australian sugar industry is characterized by horizontal separation between the stages. Often antagonistic relations between segments, particularly farmers and millers, led to each developing their systems for their own segment's benefit, without reference to the wider industry interests. Cane growing developed into a monoculture, reliant on material inputs and technological solutions, whose low labour intensity afforded substantial lifestyle benefits to growers. Such a system worked well while the industry was the worldwide cost leader, but it has contributed to stagnating yields and left growers exposed to the industry downturn caused by Brazilian competition.

Over the past few years, CSIRO and BSES research aimed at securing industry-wide cost savings included the logistical optimisation of the harvesting and transport segments, harvest scheduling to maximise sugar yield, optimisation of the length of the harvest season, logistical aspects of export marketing, and inclusion of climate forecasts in industry decisions. Our results indicate that while costs and benefits of such system changes fall unevenly on various segments of the supply chain, there is scope for industry-wide benefits from changed practices in individual segments.

Some opportunities for downstream improvements identified in our research rely on changes in the farming system. The collection of most plant matter for electricity co-generation means an end to burning before harvest or green-trash blanketing. This, in turn, affects plant nutrition and water management by farmers. Sugar production can be improved by variety selection for location and soil types. Farm-layout changes can facilitate efficient harvesting, reducing not only harvesting costs but soil compaction and stool damage, in turn increasing yield. Crop rotations with legumes have promise for agronomic improvements and growing sweet sorghum may supply the mill outside the sugarcane season. The paper describes a number of such interactions between farming systems on cane farms and the rest of the sugar supply chain, including implications for segment-by-segment profitability.

Keywords: Australian sugar industry, farming systems change.

Introduction

Since the mid 1990s, the Brazilian sugar industry has overtaken Australia's as the world's least-cost producer. The main institutional strength of the Brazilian industry is tight integration of the whole supply chain, from canegrowing to sugar marketing, usually through a single owner. This is in sharp contrast to Australia, where farms, harvesting and milling operations have mostly different owners (Figure 1, see Appendix), with potentially divergent interests. In addition, Brazil's advantage of larger farms and mills, as well as efficient transport, makes growing, harvesting, transport to the mill and milling all cheaper. The typical cost of cane delivered at Brazilian sugar mills is under A$20/t (Malcolm Wegener, University of Queensland, pers. comm.). Australian canegrowing costs were around A$30/t in the late 1990s (Chudleigh 2002). Even with cost cutting since, BSES[2] experience indicates that the mill-gate cost of Australian cane is still 50% over Brazil's[1].

Research and technology development has been instrumental in contributing the long history of success of the Australian sugar industry. Until recently, research was mostly component-based, concentrating on technological improvements. For a long time, this approach maintained Australia's technical

[1] Typical figures per tonne of cane at the mill gate: farming $20 ($15 to $27); harvest $6.50 ($4 to $20); transport $3.50 – adding up to $30/t.
[2] BSB Ltd, formerly Bureau of Sugar Experiment Stations

leadership worldwide. However, component-based research did not address the issue of system-wide efficiency and this is reflected today by low levels of supply-chain integration. In the environment of increasing cost-price squeeze for Australia, cost savings from improved integration along the supply chain is an imperative.

Optimisation of the harvesting and transport system, the supply-chain components "declared by the industry as a priority for quantum gains in productivity" (Hildebrand 2002, p. 24) was the first inter-segment research topic. Our experience indicates that, while there is scope for modest cost efficiencies (up to a dollar or two per tonne of cane), stakeholders find the gains too low to face the friction of necessary adjustment (radical reorganization of harvesting groups, extensive formal cooperation in harvesting, etc.).

Hence, it is time to look at farming again, but in a different way from that in the past: farming systems in the context of a value chain. The purpose of this paper is to:

- document ways and outcomes of farming systems interacting with other segments in the sugar supply chain, and
- offer ways of designing farming systems in an integrated manner with the rest of the industry value chain.

Impacts on cane farming systems

This section reviews instances where cane-farming systems impacted on, or were impacted by, other components of the sugar supply chain. Institutions (specifically, government regulation) and by-product use are also considered, along with segments of the main chain of harvesting, milling and marketing.

Regulation

Regulation was instrumental in creating the Australian sugar industry, and regulation impacted on every aspect of it. Farming systems were no exception, as shown by the example of fallow legumes, a traditional part of sugarcane production systems in Australia. 'Assignment' (effectively a conditional licence attached to a piece of land to grow cane and a guarantee to have it purchased by the mill) was a pivotal tool in production control until the 1990s. Increases in assigned area were authorized infrequently, in response to price rises, but typically too late to make the most of price peaks (Figure 2, see Appendix).

Among the conditions applying to caneland assignment, fallowing was prescribed on 25% of the assigned area, until these restrictions were removed in the mid-1970s (Garside et al. 2001). Under the favourable sugar prices of the mid-70s, doing away with fallowing was an easy way of increasing cane area without increasing assignments. Continuous cropping of sugarcane became widespread after the removal of compulsory fallowing. Sugar monoculture satisfies the short-term interests in the supply chain to maximize cane throughput, but this may have adverse effects in the longer term. Fears evolved that changes in soil biology under monoculture resulted in a build-up of soil-borne crop pathogens and a consequent decline in productivity. Research in the 1990s (Garside and Bell 2001) showed that cane yields of plant crops were 15-25 % higher after legume fallows, because of improved soil health and fertility. Additional benefits include reduced input costs and improved biodiversity. A potential further benefit may be income from harvesting legumes such as soybeans and peanut for grain (Garside and Bell 2001).

Harvesting

One of the greatest changes in Australian cane growing has been the replacement of manual cane-cutters by mechanical harvesters by 1979. The initial changes to whole-stick mechanical harvesting, introduced slowly since the 1930s, by themselves had little effect on the farming system. To the extent that harvesting was done in a more timely and faster manner, subsequent field operations could follow more quickly. However, it is difficult to assign benefits to this. It is the widespread adoption of chopper harvesters that has changed the farming system radically.

Planting was facilitated by the availability of billets (chopped cane stalk) for labour-saving automated billet planters that replaced the preceding models which were manually fed with whole sticks. Not only was planting rate increased, but also planting labour use was reduced by 50% through not needing a planter operator.

However, replacing manual harvesting with machines has increased harvesting losses. BSES researchers have identified ways to reduce losses in cane harvesting (Sandell and Agnew 2002). These ways centre on maintaining an optimal speed of both the harvester and the primary extractor fan (that cleans chopped cane by blowing lighter leaf matter away from heavier cane billets). In practice, this mostly requires slowing down both ground speed and fan speed. These practices, termed harvesting best practice (HBP), benefit farmers without increasing their costs. Rather, they shift costs onto harvester operators who are paid by the tonnes they harvest, but pay their crews by the hours the job takes (Antony et al. 2003a). Hence, while the farming system is unaffected, adoption of HBP depends on a change in the payment incentives. The impact of HBPs were modelled through the supply chain for various mill areas, and results for alternative scenarios of harvest-transport arrangements in Mourilyan are shown in Figure 3, (see Appendix) (Antony et al. 2003b).

Another negative effect of mechanical harvesting has been damage caused by heavy machinery: soil compaction leads to poor infiltration, slow drainage and reduced aeration, limiting root growth, nutrient uptake and crop yield (Sandell and Agnew 2002). The sugar cane industry uses harvesting and other machinery with wheel spacings at 1.6 m, yet plant cane at 1.5 m row spacings so wheel pressure from traffic occurs close to and over the stool. Yield reduction under this system is significant, up to 20% (Braunack et al. 2003). It is only recently that this impact is being addressed through 'controlled traffic', i.e., restricting machinery movements to designated paths and matching row spacing to wheel spacing. Increasing row spacing, from the conventional 1.5 m to 1.8 m, is one solution to avoid loss of yield from soil compaction, but this reduces plant density and requires further changes to the cropping system, eg, two rows of cane per hill to maintain plant density (Price et al. 2004).

Field efficiency measures the time efficiency of harvesting and is defined as the time spent cutting cane over total harvester activity time. Turning at row ends is a large component of unproductive time, typically 15% to 30%. An area where farming changes can improve harvesting efficiency is farm layout. Planting along the longest dimension of paddocks, joining paddocks, or just continuing rows, eg, on the other side of roads kept level with the paddock surface could reduce harvesting costs through better field efficiency (Sandell and Agnew 2002).

Milling

Since sugar mills carry large overhead costs because of fixed capital, it is in their interest to operate their plant for as long as possible during the year. Hence, mill operators would extend the harvest season in preference to installing extra milling capacity to increase cane throughput. On the other hand, canegrowers would prefer their cane to be harvested (and processed) in as short a season as possible around the time when sugar content peaks and the prospects for the ratoon crop are best. Thus, length of the harvesting and milling season is always a compromise between these conflicting interests.

While harvesting early in the season results in generally lower sugar yield, late harvesting has impacts on the farming system. Late cutting of the cane reduces the size of the ratoon crop (Lawes et al. 2002): at the Plane Creek mill area (south of Mackay), sugar content starts declining from the middle of October, and cane harvested after the last week of October is expected to cause increasing yield losses in the ratoon crop (Lisa McDonald, CSR Limited, pers. comm.). This impact is equalized across all growers through 'equity harvesting', i.e., by harvesting the same proportion of each farm as the season progresses.

Rainy periods during the season can stop harvesting and crushing at the mill, pushing out the finishing date of the season. There is also an increasing risk of rainfall towards the end of the year, as the rainy season approaches (Figure 4, see Appendix), potentially forcing harvesting to be abandoned altogether in extreme cases and cane to be "stood over" to the next year. This risk can be reduced by a judicious choice of varieties and appropriate decisions about when during the season to harvest younger crop classes (first or second ratoons). Local climate, slope aspect and soil types have much bearing on how fast soils dry out, and become trafficable by harvesters, after rain. Planting earlier-maturing varieties in slow-drying paddocks facilitates the completion of harvesting before the risk of rainfall increases. Traffic avenues designated for controlled traffic are compacted hard, and become passable for longer periods in wet conditions.

To start the milling season earlier, before sugar content in cane rises sufficiently, a crop other than sugarcane could be used and, thereby, cause a much larger change to the cropping system. Sweet sorghum is another sugar-producing crop that could be incorporated into the farming system, since it can be harvested in approximately 80-100 days for plant crops and 50-70 days for ratoon crops. This opens up possibilities for new areas of production (e.g. seasonally wet/dry environments without irrigation infrastructure) and/or new patterns of feedstock supply, outside the current sugarcane-harvesting period. Productivity in sweet sorghum crops (in terms of efficiency with which radiation energy is transformed into biomass) is of the same order as sugarcane crops, but the product has a higher proportion of reducing sugars and is less well suited to sucrose production. Instead, it could extend the efficiency of by-product utilization by mills by providing sugar to an ethanol plant and fibre for co-generation (Keating et al 2003). So far there are no commercial applications of sweet sorghum in the Australian sugar industry.

Marketing

Since the Australian sugar industry is not working as a value chain, marketing imperatives have had little impact on the farming system. For example, while there is usually a market premium for sugar delivered in June, neither mills nor growers are interested in starting the season early because the cane payment system that has been used in the Australian industry for decades is not conducive to channelling such premiums to the early starters who have to incur lower sugar yields. Recent changes to the regulations controlling cane payment have created the opportunity for more flexibility but agreement between growers and millers to introduce such innovations has been achieved in only a few cases.

The certified organic segment of the industry has undertaken the most radical redesign of its farming system to satisfy its customers (Antony et al. 2004). Although some growers have long used biological farming principles in their conventional cane crop, more widespread conversion to organic canegrowing is not possible without a market that pays the premium necessary to cover the additional costs. Organic canefarming shares the principle common in organic farming that crop rotations and management of soil biological function and fertility sustain productivity and mitigate weed, disease, and pest impacts (Stockdale et al. 2001). Implementation of this principle in organic sugarcane production involved grassroots innovation based on farmer experimentation. Organic farmers have been developing adventurous rotations incorporating various legumes and cereal crops, sometimes as inter-cropped fallows and companion crops, to build stocks of organic nitrogen and carbon in soils. Quick-acting inorganic fertilizers are replaced with strategic, integrated applications of legume fallows, organic nutritional sources and attention to trace elements. Pest and disease control in organic farming relies on prevention based on the vigour of crops grown in biologically active soils and the selection of appropriate varieties. However, such an approach carries significant risks, requiring inadequately tested tactical responses to infestations. Use of cultivation for weed control is effective, but has cost and environmental implications.

By-product use: non-cane biomass

If a single product, sugar, is the supply-chain objective, only the cane (stalk) is of interest. In this system model, bagasse (the fibre remaining after crushing) is burned to generate power for the sugar mill, while leaves and tops of the plant are disposed of at least cost. Conventional pre-harvest burning left the tops only, and these were dropped on the ground during harvesting. Green cane harvesting leaves behind a trash blanket of leaf matter and tops, which acts as a weed control, which may be supplemented with herbicide application. As industry profits from sugar alone have been shrinking, new applications for the non-cane biomass by growers and by mills have emerged to add to earnings. These tend to impact on the farming system.

Grower use

Increasing demand for gardening mulch and emergency cattle fodder has stimulated the collection of the trash blanket, providing growers with additional sources of income that may not be much less than their sugar payments of around $2000 per hectare.

Mill use

Sugar mills have traditionally generated their own electricity needs in co-generation plants using steam excess to cane processing. Increasingly, they are trying to improve profitability through generating more electricity for sale, either by improving the efficiency of the existing low-pressure system or by installing new high-pressure boilers. For an average mill, the former involves a $5m investment for an alternator, producing 7 MW export electricity for around 50% of the time during the crushing season. This co-generation option has been used for the Tully, South Johnstone and Proserpine mills. Installation of a new boiler is mainly part of mill expansion or extensive overhaul. A minimum investment of $50m is required for a high-pressure boiler, alternator and general improvements in mill steam efficiency, providing around 40 MW for 90% of the season. Keating et al. (2002) estimated financial returns to these options at 10-13%. The income generated by mills from electricity sales is not shared by growers (except in the case of cooperative mills where the mill owners are the growers).

Increasing grower costs and/or reduced yields are not usually considered when calculating the benefits of by-product use. The removal of protective ground cover has mostly negative agronomic impact. Unless overly wet soils are a problem (in cooler regions or waterlogged soils), moisture loss reduces yields. Denmead et al. (1997) have shown that a trash blanket significantly reduces evaporation, and the rule of thumb of growers at Rocky Point (just south of Brisbane) is that “the trash blanket is worth four inches of rain”. Maryborough growers currently using trash blanketing estimate that removing all trash will require three additional cultivations to control weeds.

Purposeful system design through value-chain modelling

One of the most successful innovations in the Australian sugar industry has been green cane harvesting. This was made necessary by the risk of losses in burnt cane harvested with a long delay caused by rain after burning, and it had the added benefit of moisture retention in the soil and weed control. All supply-chain segments apart from cane harvesters clearly benefited from this innovation, even though this was introduced at the expense of a 50% increase in the cost of harvest from burnt to green. However, this outcome was far from planned, and neither is it typical of supply-chain impacts of introducing new technologies in the sugar industry.

More common were unintended negative flow-on effects through the supply chain as a result of changes in individual supply-chain segments. Gains in one segment may have been reduced or offset by losses in others. This can reduce industry-wide results or prevent cooperative behaviour through the supply chain that is necessary for the adoption of the new technique. It is proposed here that value-chain modelling and ex-ante assessment can reduce such undesirable consequences.

Value-chain modelling is novel in the Australian sugar industry, and a research project undertaken by CSIRO's Tropical Landscapes Program, BSES Limited, and the Sugar Research Institute is an early example (Archer et al. 2004). Our approach is one of agent-based modelling reflecting the views and judgements of stakeholders from different segments participating in the assessment. The analytical framework uses existing models of supply-chain segments (for agronomy, harvesting and in-field haulage, cane transport to the mill, and milling) (Figure 5, see Appendix). Simplified versions of these, with key fixed parameters (the 'diamond models') reflecting a social model of stakeholder views and system parameters (the 'Reference Group filter'), are linked together in a biophysical/financial framework. Compared to current practice, our approach more completely takes account of impacts of changes throughout the whole system and identifies bottlenecks or areas where further investigation is required.

The first application of the approach and the model was made in the Maryborough mill area where the installation of an electricity co-generation plant is being considered. To make the plant as economic as possible, bagasse would be supplemented with non-cane biomass. Initial results indicate that the co-generation plant by itself may not be a profitable proposition. Additional harvested material would bring marginal benefits to cane harvesters with the current payment regime. However, the removal of the trash blanket would reduce yields and require additional cultivations to suppress weeds, disadvantaging canegrowers in the mill area by millions of dollars. The result may in part be a reflection of specific conditions in the Maryborough region. However, more broadly, the current value of electricity cogeneration may only be able to cover the costs of investment in specific circumstances. Such conditions include high sugar yields per tonne of cane and low capital requirements throughout the value chain.

Conclusions

During the history of the Australian sugar industry, technical changes in any one supply-chain segment were typically implemented without reference to impacts on other segments. Farming systems have endured such buffeting from downstream segments, with both positive and negative impacts. On the other hand, some changes initiated in the farming system had knock-on effects on other segments. Yet other changes in the farming system that would have been in the interest of downstream segments were not implemented due to the lack of incentives. Such an insular approach to introducing new technology has contributed to alienation and animosity between supply-chain segments in the industry.

Value-chain planning offers an alternative to segment-focused technical changes whose knock-on effects are neither foreseen, nor considered. Full impact assessment through the value chain, complete with the identification of likely first-round winners and losers, offers the opportunity to develop a compensated, 'win-win' outcome by quantifying potential overall benefits and their distribution. It is then up to the industry to make sure that benefits from new technology are shared to secure cooperation.

The use of holistic optimisation in the industry is a means by which novel and sustainable solutions can be found by including farm management as well as representatives of other supply-chain segments in the decision-making process. The value-chain model facilitates a "Thinking Together" approach by providing a simulation tool whereby scenarios can be developed and costed. In most developed applications, extensive system re-design becomes a possibility through value-chain modelling.

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Appendix

Figure 1. The Australian sugar supply chain

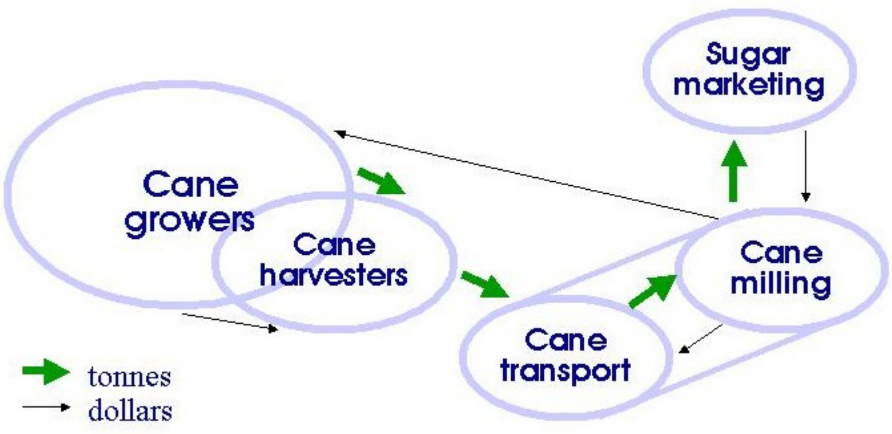

Figure 2. Queensland cane assignments and export sugar prices

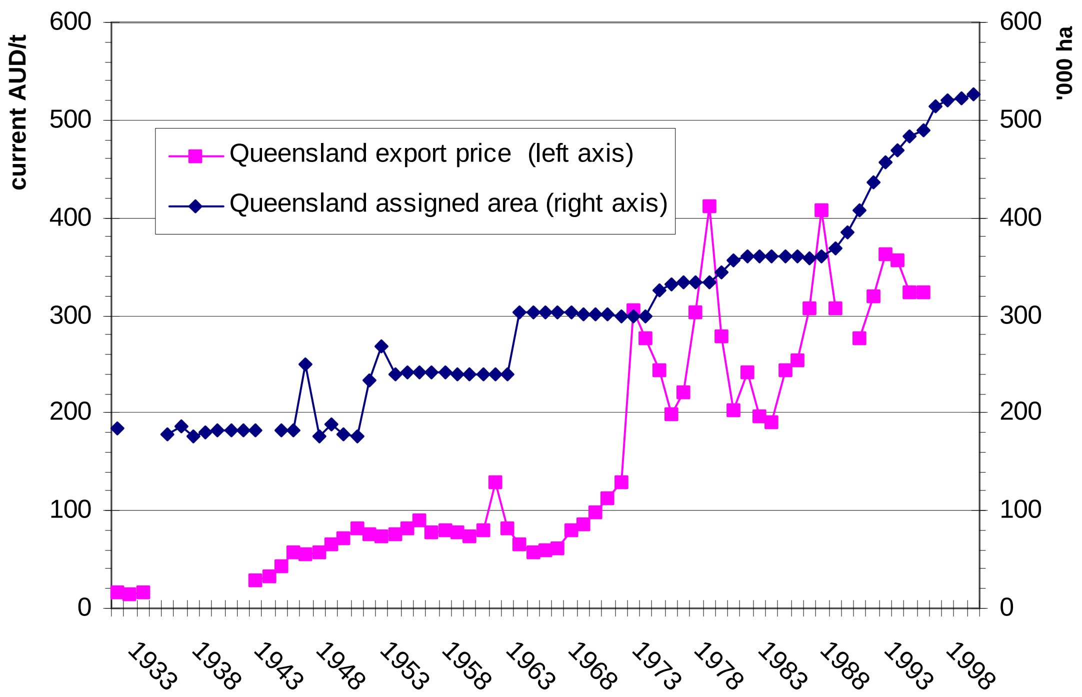

Figure 3. Supply-chain-wide implications of best-practice harvesting

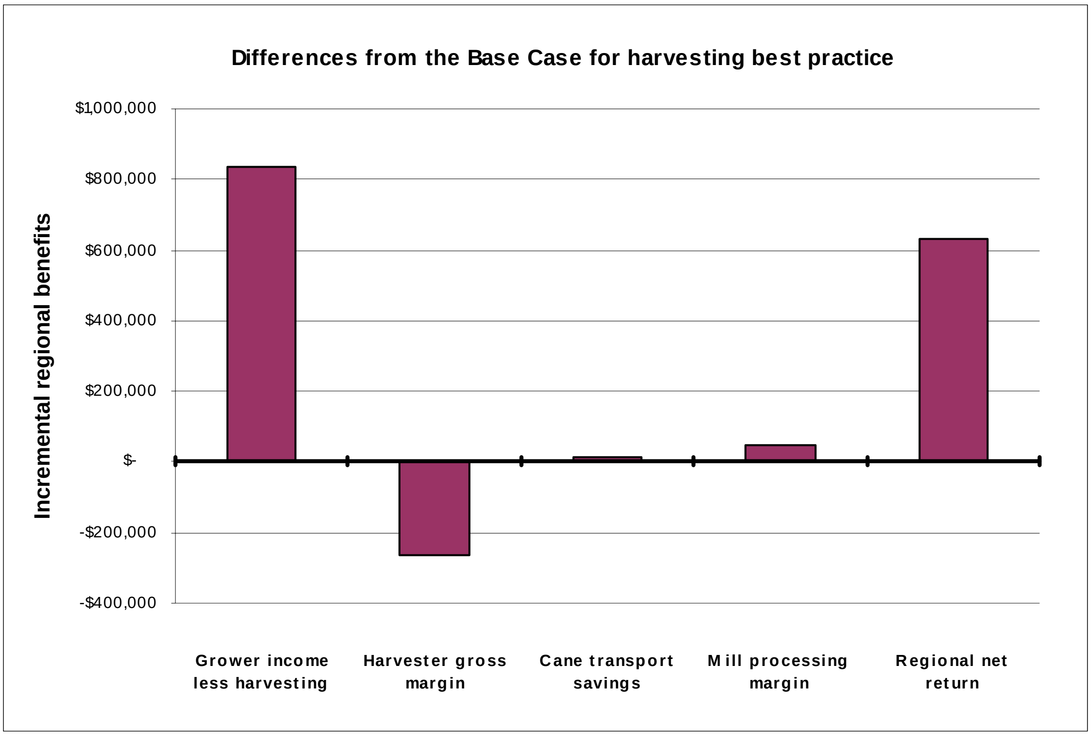

Figure 4. Weekly rainfall figures at Plane Creek from 1889 to 2002

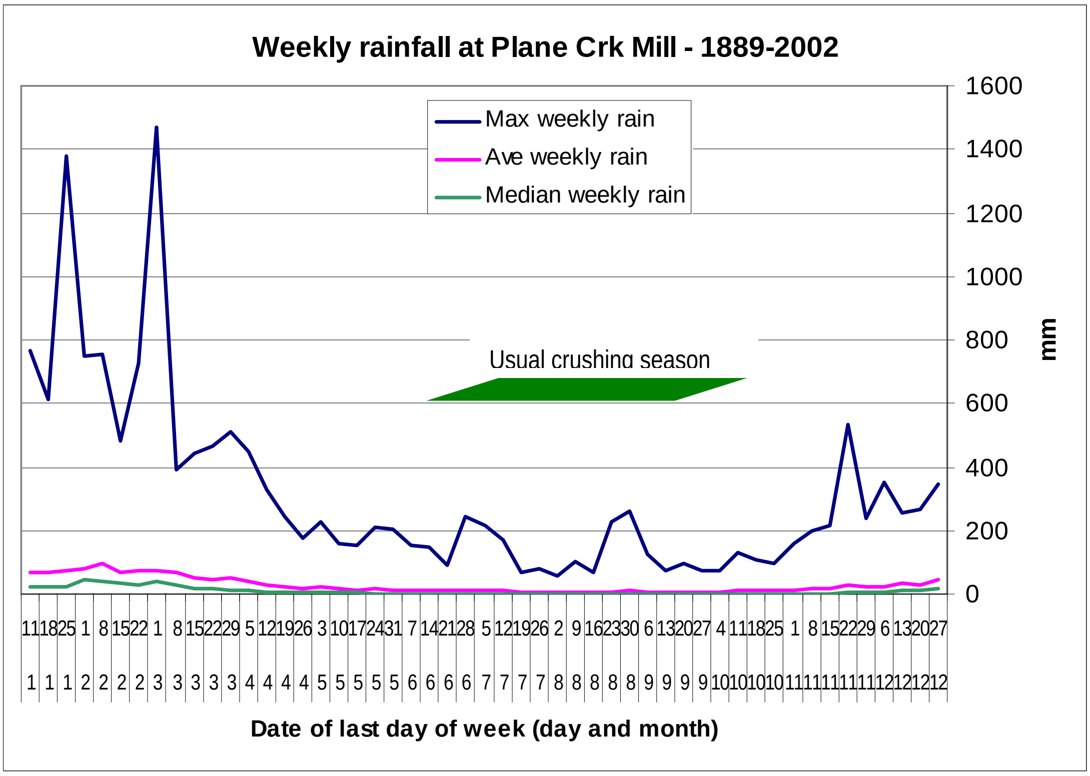

Figure 5. Value-chain modelling for the Australian sugar industry